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ABSTRACT

The relationship between trial-to-trial changes in free recall and eight intelligence and memory abilities was investigated in a sample of 72 college students. Despite identical acquisition curves under immediate and delayed recall, differences between the two groups in correlational pattern between recall performance and abilities were striking. Under delayed recall intelligence variables predicted recall performance best, particularly in late trials. Memory variables were most predictive under immediate recall, especially in early trials. These results point to the need of aligning components of abilities and learning performance as a rationale for the modification of intellectual competence. References and tables are included. (Author)

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The relationship between trial-to-trial changes in free recall and eight intelligence and memory abilities was investigated in a sample of 72 college students. Despite identical acquisition curves under immediate and delayed recall, differences between the two groups in correlational pattern between recall performance and abilities were striking. Under delayed recall intelligence variables predicted recall performance best, particularly in late trials. Memory variables were most predictive under immediate recall, especially in early trials. These results point to the need of aligning components of abilities and learning performance as a rationale for the modification of intellectual competence.

# Aligning Components of Intelligence and Learning Performance: A Proposed Rationale for Educational Intervention

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Intervention into the course of intellectual ontogeny traditionally has been aimed at the design and provision of learning experiences that, hopefully, would alter the course of development in culturally disadvantaged children (Sigel, 1971). It is fair to state, however, that most intervention programs have not produced the desired outcomes (Jensen, 1969; Kohlberg, 1968; LaCrosse, Lee, Litman, Ogilvie, Stodolsky, & White, 1970), probably due to the overly pragmatic orientation of such efforts which rarely were guided by some theoretical conceptions of the nature of intelligence and intellectual development, and those experiences that influence and modify specific abilities (Labouvie, 1973; Sigel, 1971).

In the case of the target or criterion behavior of educational intervention, unfortunately, the specification of an appropriate conceptual model has been particularly difficult for two major reasons. Psychometric conceptions of intelligence, on the one hand, were highly pragmatically oriented (Bijou, 1971; Jensen, 1969) and centered mainly on a one-sided, descriptive analysis of covariation patterns among multiple performance measures (Gewirtz, 1969; Baltes & Nesselroade, 1973); they were not supplemented, however, with a theoretical framework that specifies the antecedents and processes involved in the acquisition of intellectual performance, and thus did not provide sound theoretical groundrules from which techniques of intervention could be deduced.

Learning approaches to the ontogeny of cognitive behavior (Berlyne, 1970; Flavell, 1970), on the other hand, have visualized intellectual development in terms of an increasingly effective use of mediational devices in learning situations, and have enumerated those experiential conditions that might facilitate this progress. They showed little concern, however, with demonstrating that the many different changes isolated in discrete tasks converge, indeed, into an interrelated set of developmental progressions.

A number of authors therefore have suggested that it would be useful to attempt a systematic integration of psychometric and learning accounts of the development of intelligence (Anastasi, 1970; Baltes & Labouvie, 1973; Baltes & Nesselroade, 1973; Ferguson, 1954; Fowler, 1969; Gagné, 1968; Jensen, 1971; Staats, 1971; Whiteman, 1964) by discussing intellectual ontogeny in terms of the acquisition of certain generalized behavioral skills. The basic assumptions underlying such learning models of intellectual development have been succinctly summarized by Jensen (1971, pp. 39-40): "The sets of habits which we identify as intelligent behavior are seen as being built up through the acquisition of habits and chains of habits which interact to produce complex behavior. Mental development is thus viewed as the learning of an ordered set of capabilities in some hierarchical or progressive fashion, making for increasing skills in stimulus differentiation, recall of previous learned responses, and generalization and transfer of learning." Thus the formation of broad, transferable information processing or problem solution strategies--as identified in the traditional developmental learning literature (Jensen, 1971)--is seen to provide the link between psychometric ability systems on the one hand, and effectiveness in learning situations on the other.

Although such a re-conceptualization is appealing on a theoretical level, attempts to demonstrate common components in ability test and learning performance

have not been very successful to date. About a decade ago, a number of studies reported attempts to identify the common processes cross-linking the two areas by the examination of correlational patterns between ability test and learning performance (for summaries, see Dunham, Guilford, & Hoepfner, 1968; Fleishman, 1972; Roberts, 1968). In general, this work has not produced systematic and interpretable cross-linkages, although it has tended to support the conclusions (a) that the pattern of abilities related to a particular task depends upon specific task conditions, and (b) that ability-learning relationships undergo systematic changes as task proficiency increases (Fleishman, 1972; Fleishman & Bartlett, 1969; Frederiksen, 1969, Roberts, 1968).

The failure thus far of finding many meaningful and replicable interrelations is not surprising if one considers the highly exploratory nature of this research. On a theoretical level it reflects, similarly, the need of formulating models that provide a taxonomy of basic processes, or genotypes (Jensen, 1967) and their relation to performance in different tasks, treatment conditions, etc.

The present study involves an attempt to demonstrate that learning processes and abilities can be systematically aligned, and that the obtained interrelationships vary in a systematic manner with experiential and treatment related parameters. Following a preliminary model by Jensen (1969; 1971; Jensen & Rohwer, ) it is hypothesized that learning-ability realtions will be mediated by two classes of strategies: rote memorization vs. abstract organizational skills.

A free recall task is used to demonstrate practice and treatment related changes in learning-ability relationships. Free recall has been shown to be a task particularly sensitive to studying higher-order strategies reflected in subjects' tendency to impose conceptual relationships on the material presented, such as in clustering and subjective organization (c.g., Shuell, 1969; Tulving,

1962, 1968). Moreover, the amount of mediational activity can be fairly easily manipulated by such parameters as practice, age, presentation of material, and timing of recall.

In addition to practice, timing of recall was used in the present study to manipulate mediational activity assumed to monitor changing learning-ability relationships. Previous research suggests that the insertion of a delay between stimulus presentation and recall results in increased mediation, as exemplified by a reduction in the amount of primary, input-dependent (e.g., Atkinson & Shiffrin, 1968; Postman & Phillips, 1965) and an increase in the amount of secondary, input-independent organization (e.g., Cofer, 1967, Cofer, Bruce, & Reicher, 1966). Thus two main hypotheses were formulated, one involving differential recall-ability relationships between immediate and delayed timing of recall conditions, and the other involving changes in the ability-recall covariation pattern as a function of stage of acquisition. Specifically, it was expected that (a) recall measures show a strong relationship to general intelligence under delayed recall, whereas under immediate recall memory variables show the strongest relationship to recall performance, and (b) the overall contribution of memory variables to recall performance is strongest during early stages of acquisition, whereas later stages of acquisition exhibit an increasing relationship with intelligence variables

## Method

Subjects. A total of 72 male (N = 34) and female (N = 36) undergraduates (mean age: 19 years and 8 months) enrolled in introductory psychology classes served as subjects on a volunteer basis. They were randomly distrubuted into two groups (Delay vs. No-Delay).

Recall Task. The learning task consisted in the recall of 30 familiar objects presented pictorially. Each stimulus was presented on a screen for two seconds, with interstimulus intervals of about 1 second each. A presentation of all 30 stimuli, followed by a 90 second recall interval, constituted one trial. During the first trial only, the names of the stimuli were given orally upon presentation. Practice was continued until a total of 16 trials was completed. For each trial, a random series of the 30 stimuli was generated, with the restriction that each stimulus appear in each order just once, and that it be preceded or followed by any particular stimulus just once. The order of these random sequences across trials was held constant for all subjects.

In the Delay condition, an interval of 30 seconds of letter cancellation was inserted between presentation of the last stimulus in each trial and recall. Delay was followed by 90 seconds of recall time, during which the subjects were to write down the stimuli they recalled in any order they wanted. In the No-Delay condition, recall followed immediately upon presentation of the last stimulus in a trial. In order to equalize inter-trial intervals, the 30 seconds of letter cancellation followed recall in this condition. For both conditions, recall and letter cancellation sheets were prepared and arranged in booklet form.

Marker Variables. All marker tests were selected on the basis of previous factor analytic work aimed at structuring both the universe of ability and memory functions. Thurstone & Thurstone's (1962) Primary Mental Abilities (PMA) test was chosen to mark the intelligence domain. This test includes four subtests: Verbal Meaning, Number Facility, Reasoning, and Space. Tests of memory abilities were obtained from a publication by Kelley (1964) as well as the French, Ekstrom, & Price (1963) Kit of Reference Tests for Cognitive Factors. Specifically, four tests were included to mark the memory domain: Object Number (a test of associa-

tive memory), Auditory Number Span, Recognition (a test of 'rote' memory), and Memory for Words (a test of 'meaningful' memory).

Procedure. The experiment was conducted in three sessions. The first two sessions comprised the Memory and PMA tests, which were given to groups of about 30 subjects at a time with the Memory tests administered first. The recall task was given in a third session, where groups of about six subjects were run at a time.

Data Analysis. The analyses of the data examined (a) main and interaction effects in recall performance by means of analyses of variance, and (b) changes in the correlational pattern between marker variables and recall performance both across stages of acquisition and experimental treatments.

Recall scores were obtained by computing the number of correctly recalled stimuli at each of the 16 trials for each subject. These scores were collapsed into blocks of four trials, and the mean number of items correctly recalled per subject constituted the recall scores used in the final analysis.

A 2 (Delay vs. No-Delay) by 2 (Sex) by 4 (Blocks of trials) analysis of variance with repeated measurement across the last factor was performed on the recall scores. This analysis was preceded by testing the variance-covariance matrices associated with the repeated measurement conditions under Delay and No-Delay for equality as described by Winer (1962).

In order to be able to interpret changes in correlational pattern, it was necessary to ascertain that such differences are not related to either (a) pre-experimentally existing differences in the correlational pattern among the variables, or (b) reduction of variance in the recall scores at later stages of acquisition. The 4 by 4 variance-covariance matrices associated with intelligence and memory variables under both experimental conditions were therefore computed

and tested for equality. Similarly, equality of variance was tested for the recall scores by Hartley's test (Winer, 1962).

Correlational analyses were aimed specifically at the hypotheses to be tested. First, a 12 by 12 correlation matrix was computed, with the 4 PMA subtests, the 4 Memory tests, and the 4 recall scores entering as variables. Examination of trial and treatment related differences in the covariation among recall and marker variables then proceeded in analogy to an analysis of variance design. Thus, in order to test differences in the overall correlational pattern between Delay and No-Delay, canonical correlations were run with either intelligence or memory tests entering as the first variable set, and the four recall scores as the second. Changes in trial-to-trial covariation pattern were examined by computing sets of multiple correlation coefficients between either intelligence or memory variables as predictors, and any of the four trial scores as criterion variable. These multiple correlations were computed both separately for the Delay and No-Delay conditions and for the combined groups.

## Results

Recall Performance. Test of the variance-covariance matrices associated with the repeated measurement recall scores under Delay and No-Delay showed that the null hypothesis of equality of covariances could be retained (chi square = 15.8, df = 10; $p < .10$). Analysis of Variance on the recall scores revealed a strong effect for trials ($F = 820.51$, df = 3.204; $p < .01$). None of the other effects was significant. The trial effect is shown in Figure 1. Note that virtually the same

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Insert Figure 1 about here

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acquisition curves are obtained for the Delay and No-Delay groups.

Correlational Analyses. Tests of the variance-covariance matrices associated with the intelligence and memory marker set for Delay and No-Delay showed no significant differences in the covariation patterns (PMA: chi square = 4.55, df = 10, $p > .10$, Memory: chi square = 11.60, df = 10, $p > .10$). Trial-to-trial changes in the variance of the recall scores similarly are not significant (Delay: $F = 1.20$, df = 16, 36, $p > .10$; No-Delay: $F = 1.35$, df = 16, 35, $p > .10$). Thus, the recall-marker relationships presented below do not seem to be confounded with statistical artifacts.

The trial-to-trial correlations between recall performance and each of the intelligence and memory markers are shown in Figures 2 and 3. Note first that

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Insert Figures 2 and 3 about here

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most of the marker variables do not exhibit a fixed relationship to recall performance but that the overall pattern suggests systematic trial and treatment related changes. At first glance, particularly impressive are (a) the rise in recall-intelligence correlations for the PMA variables (Figure 2) and later stages of recall in the Delay group, and (b) the decline in recall-memory correlations for the Recognition and Memory for Words tests (Figure 3) as task proficiency increases.

Table 1 summarizes the multiple and canonical correlations which were computed to obtain a statistical assessment of these differences in correlational patterns. The over-all relationship, as indicated by the canonical

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Insert Table 1 about here

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correlation coefficients (last column of Table 1) shows divergent results for the two treatment conditions. Although only the canonical correlation between

PMA variables and recall scores in statistically significant, the pattern suggests that intelligence variables relate strongest to delayed recall, whereas memory variables are most predictive under immediate recall.

The multiple correlations between marker variables and trial scores at specific stages of acquisition (first four columns of Table 1) also support this notion of a differential relationship, in addition to verifying the hypothesized trial-to-trial pattern. On the one hand, considering delyaed recall, there is an increase in the multiple correlation between recall and intelligence tests, while the correlation between memory variables and recall performance (being insignificant to start with) shows a systematic decrease over trials. On the other hand, considering No-Delay recall performance, it is the set of memory variables which shows a strong initial correlation to recall, followed by a systematic trial-related decrease, whereas the intelligence variables in this case do not exhibit a significant relationship to recall. Thus, intelligence variables are found to be good predictors for later stages of delayed recall, while memory variables are good predictors for immediate recall, however, at early stages of acquisition only.

## Discussion

The surprisingly clear-cut pattern of the present data is in clear contrast to previous, rather pessimistic evaluations of attempts of cross-relating learning and intelligence test performance (e.g., Stevenson, 1970). In agreement with the major hypotheses of the present study, it is found that the formulation of differential predictions about the interrelations between specific sets of abilities and recall performance under varying conditions may be a powerful tool in organizing learning ability interrelationships. Thus, in agreement with the major hypotheses of the study, it is found (a) that variables of the general intelligence type are good predictors of recall performance under delyaed recall, while under immediate recall, variables of the "rote" memory type best predict recall performance, and (b) that this pattern is not fixed, but undergoes systematic trial-related changes.

The clear differentiation of the recall-ability correlation pattern is the more impressive since the univariate acquisition patterns for the two treatment groups do not show any differences. Within the traditional context of univariate experimental methodology, such a finding usually would be interpreted as an indication of equivalent processes operating under the two treatment conditions. This present finding, therefore, strongly underscores the contention that a single performance parameter - such as number of correctly recalled items - is a rather insensitive index of the complex changes in underlying processes that may be induced by slight variations in task format. Within the

multivariate context of the present study, on the contrary, it appears that the observed changes are highly complex and must probably be seen as varying along multiple dimensions. Thus, the present data convincingly argue for the need of utilizing multi-measured assessments of performance changes in learning tasks in order to locate change phenomena that are apt to be neglected if consideration is given to single performance parameters only.

In a similar vein, the emergence of the clear treatment-related differentiation of learning-ability patterns suggest to the psychometrician the usefulness of attempting to move the traditional ability concept into a process-oriented framework by applying theory-related manipulation in the explication of individual difference concepts. Thus, the present authors do not share the pessimism expressed by some authors (e.g., Bijou, 1971; Hunt & Kirk, 1971) who feel that the ability concept is being rendered obsolete. Such pessimism is justified only if, as has often happened (Anastasi, 1970) ability concepts are viewed as organismic state variables that have an autonomous and self-explanatory status. If such state variables are restated, however, in terms of theoretically relevant process constructs (Melton, 1967) and explicated in terms of their learning ontogeny, they should continue to offer a significant contribution towards the understanding of intellectual ontogeny.

Despite the simplicity of the model adopted in the present context, its power in systematically aligning components involved in learning performance and abilities is most encouraging. From

a theoretical perspective, the present findings may be related to models conceptualizing the interaction between learning and ability systems as the outcome of developmental learning sequences. Jensen (1971), for example, has recently related his Level I and Level II abilities in a hierarchically ordered developmental sequence that conceptualizes processes of abstraction as built upon associative processes, which in turn are a necessary but not sufficient prerequisite for the manifestation of Level II abilities. Level I abilities involve little elaboration on stimulus input, so that there is high correspondence between stimulus input and response output. Level II abilities, on the other hand, involve mediation, that is elaboration and transformation of stimulus inputs. A similar model has been formulated by Gagne (1968) who describes intellectual ontogeny as "the building of increasingly more complex and interacting structures of learned capabilities" (p. 198). Thus on the one hand, abilities are seen as the ontogenetic product of a cumulative learning sequence. On the other hand, once abilities are acquired, they will in turn modify subsequent new learning.

The pattern of trial- and treatment-related differences of the present study appear to be in good agreement with such a developmental interpretation. Since both learning and ability test performances are seen to vary on a dimension of rote-conceptual solution strategies the correlation pattern between abilities and learning would, consequently, be determined by the extent to which both sets of tasks occupy a comparable level on the abstract-role continuum. Thus, first, the treatment-related differences in

correlations appear to exhibit a strong Level II component under delayed recall, while under immediate recall there is a preponderance of Level I processes. Second, however, the trial-related overall increase in the contribution of intelligence variables, paralleled by a corresponding decline in the contribution of memory variables towards predicting recall performance, demonstrates that learning and ability systems interact differentially not only as a function of task demands but also as a function of task proficiency. Such short-term changes are of particular interest in a developmental context if they are seen to parallel or to simulate (Anastasi, 1970; Baltes & Coulet, 1971) naturally occurring developmental processes of the type described, for instance, by Gagne (1968) and Jensen (1971).

The present results seem to carry additional implications tied in with aspects of educational intervention and technology. Bijou (1971), for example, has forcefully argued that the conceptual planning of intervention into the course of intellectual ontogeny would be significantly advanced if the frames of reference for the theoretical analysis of intellectual processes on the one hand, and for educational engineering by means of application of learning principles on the other, were the same. Thus in contrast to the still prevalent shotgun approach at modifying ability patterns, systematic theoretical efforts are called for in all attempts at linking specific components to specific ability dimensions. The present findings suggest even further that such heuristic models must account for changes in learning-ability relationships as acquisition processes. Eventually, therefore, educational programs would

need to be aimed at facilitating the operation of different ability components as task mastery progresses. Obviously, however, current knowledge of such task-ability-learning interactions is both vague and restricted in scope.

Similar perspectives hold true of issues associated with the evaluation of educational interventions in terms of subsequent changes in ability scores. Consider, for example, the possibility that the somewhat discouraging results obtained in cognitive intervention research (e.g., Jensen, 1969) might be largely due to the failure of properly aligning, in the evaluation phase, learning and ability components. This seems particularly true if general measures of intellectual performance, such as IQ, are used as a criterion in evaluating the effectiveness of educational programs.

All these considerations seem to further underline the quest for vigorous research into the developmental interaction between ability and learning components. The cogent pattern of the present data lends strong support to the proposition that such research will continue to be of both theoretical and practical import.

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Table 1

Summary of Multiple and Canonical Correlation Analyses

| Treatment | Blocks of Trials | | | | |
|---|---|---|---|---|---|
| Group | 1-4 | 5-8 | 9-12 | 13-16 | 1-16 |
| | | | PMA | | |
| Delay | .32 | .29 | .54* | .53* | .77** |
| No-Delay | .18 | .30 | .23 | .23 | .44 |
| Combined | .19 | .26 | .33 | .32 | --- |
| | | | Memory | | |
| Delay | .42 | .32 | .37 | .29 | .45 |
| No-Delay | .56** | .55** | .38 | .32 | .60 |
| Combined | .46** | .40* | .35 | .28 | --- |

Note: Cell entries in first four columns are multiple correlation coefficients using PMA or Memory Variables as predictors and mean recall scores at a specified block of trials as criteria. Cell entries in last column are canonical correlations using PMA or Memory Variables as predictors and the four recall scores as criterion set.

*$p < .025$

**$p < .01$

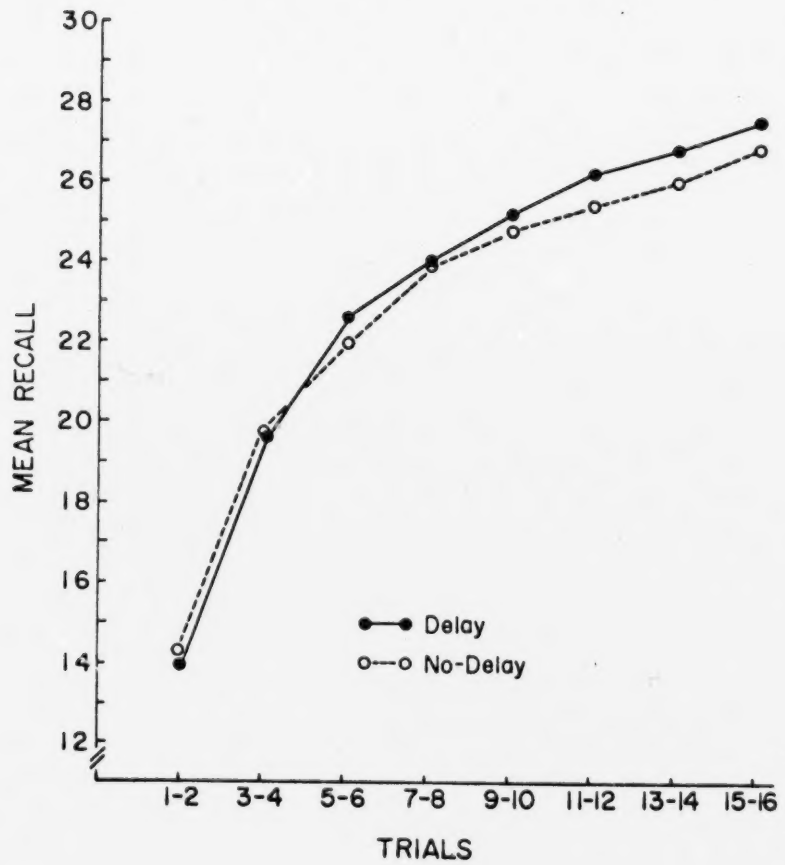


Figure 1: Trial-to-trial changes in correctly recalled items under Delay and No-Delay

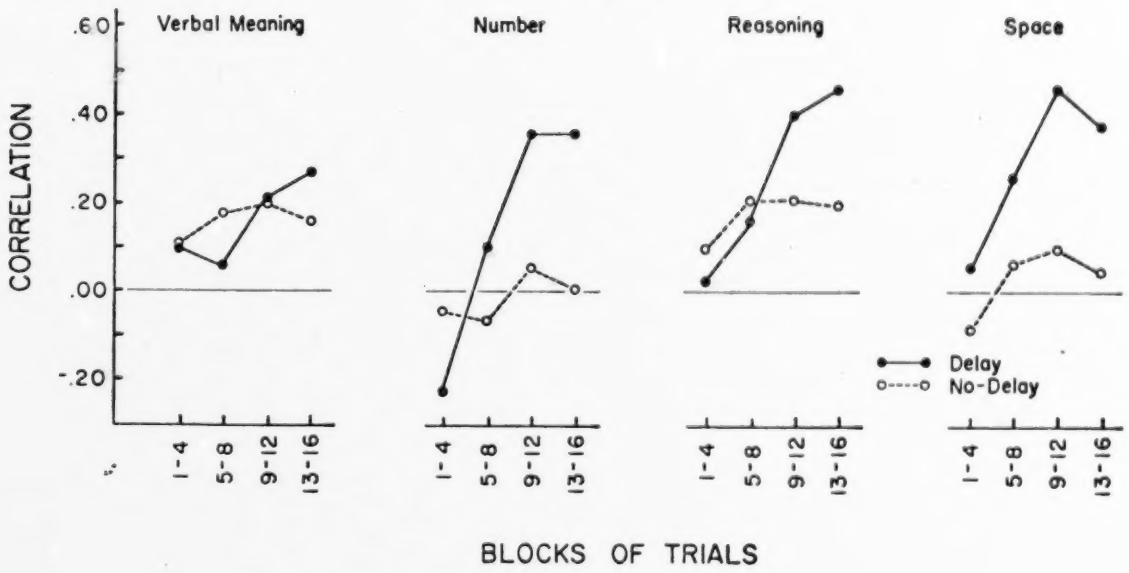


Figure 2: Trial-to-trial changes in correlation between recall scores and intelligence markers under Delay and No-Delay

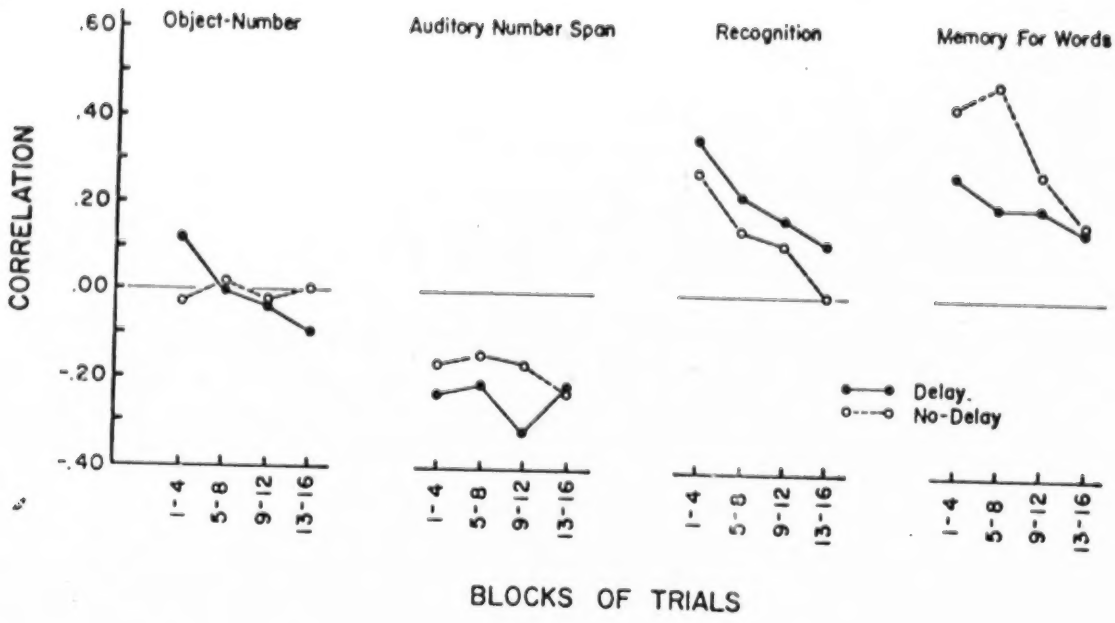


Figure 3: Trial-to-trial changes in correlation between recall scores and memory markers under Delay and No-Delay